The types and severity of complications associated with interscalene brachial plexus block anesthesia: Local and national evidence

Tim R. Lenters, MD,[a] Joanna Davies, MBBS, FRCA,[b] and Frederick A. Matsen III, MD,[a] *Seattle, WA*

Interscalene brachial plexus block is a commonly used anesthetic. However, substantial complications can be associated with its use. Our study included 15 years of data from a local medical center and 3 decades of records from the national American Society of Anesthesiology Closed Claims Project. The hospital had 27 peripheral neurologic injuries, 3 central nervous system complications, 6 respiratory complications, and 5 cardiovascular complications. Of these complications, 14 were still present at the most recent follow-up, some causing major compromise of the patient's comfort and function. All central blocks, local toxicities, and respiratory complications resolved. In the hospital series, more experienced anesthesiologists tended to have lower complication rates. The American Society of Anesthesiology Closed Claims database had 20 peripheral neurologic injuries, 10 respiratory complications, 5 central nervous system complications, 4 deaths, 2 emotional disturbances, and 1 other unknown event. Of the complications, 19 were described as permanent. Interscalene brachial plexus block can be accompanied by substantial and disabling complications, especially when administered by less experienced anesthesiologists. (J Shoulder Elbow Surg 2007;16:379-387.)

Interscalene brachial plexus block (ISB) is frequently used for shoulder surgery. It can be associated with shorter stays in the post-anesthesia care unit, less postoperative pain and narcotic usage, less nausea, fewer unplanned hospital admissions, and shorter hospital stays.[9,12,16,22,33,38,47] Furthermore, the technique has been described as safe and effective, especially when performed in a dedicated setting with experienced hands.[3,7,10,11,25,27,30,33,37,40] "Successful" blocks have been reported in 87% to 100% of cases when performed by anesthesiologists who routinely use this technique.[7,19,28,37,45] However, the published literature does not emphasize the type and severity of adverse outcomes that may accompany ISB when this method is applied in the general practice of anesthesiology.

This report uses the data from a local medical center staffed by general anesthesiologists and from a national database of closed malpractice claims to illuminate the nature and severity of complications that may accompany ISB when practiced in settings outside centers expert in this technique. This information will enable surgeons, anesthesiologists, and patients to be aware of the possibility of the substantial and enduring complications that may accompany ISB.

MATERIALS AND METHODS

Data from a local medical center

As an example of a general anesthesiology practice, we selected a local medical center where blocks were performed by general anesthesiologists. After obtaining institutional review board approval, we reviewed the records of patients who had complications associated with the use of ISB at this medical center. These patients were identified by a search of the orthopaedic department's morbidity and mortality records from January 1994 to January 2005 and the anesthesia department's continuous quality improvement records between January 1990 and January 2005. All orthopaedic cases with an adverse outcome, even minor complications requiring no treatment, were included in the orthopaedic morbidity and mortality database. Anesthesia complications, including any patient injury, major change in anesthesia plan, or unanticipated anesthesia problems, were included in the anesthesiology continuous quality improvement database. Each complication was counted

From the Departments of [a]Orthopaedics and Sports Medicine and [b]Anesthesia, University of Washington Medical Center.

Reprint requests: Frederick A. Matsen III, MD, Department of Orthopaedics and Sports Medicine, University of Washington Medical Center, 1959 NE Pacific St, Box 356500, Seattle, WA 98195 (E-mail: *matsen@u.washington.edu*).

1058-2746/2007/$32.00

doi:10.1016/j.jse.2006.10.007

only once, even if it was identified in both the orthopaedic and anesthesiology databases. After identification of subjects, medical records were reviewed to collect data regarding the nature and duration of the complication, the nature of the surgery, and the technique of ISB. Complications were classified as related to (1) peripheral nerve function, (2) respiratory function, (3) central nervous system (CNS), or (4) cardiovascular function. Complications that had not resolved with more than 6 months of follow-up were designated as chronic.

From January 1994 to January 2005, the interval for which both orthopaedic and anesthesiology data were available, 3,172 interscalene blocks were administered at the medical center. For those anesthesiologists who encountered a complication, we were able to recover the total number of blocks that they had performed during the time period under study. The complication rate was then compared with the number of blocks performed by each anesthesiologist.

Data from a national database

The American Society of Anesthesiology (ASA) Closed Claims Project is a structured evaluation of adverse anesthetic outcomes obtained from the closed claims files of 35 US professional liability insurance companies.[13,26] The database collects information from cases that have resulted in litigation and provides a forum in which to report the data. We searched this database for adverse events related to the administration of ISBs over the last 3 decades. Complications were again classified as related to (1) peripheral nerve function, (2) respiratory function, (3) CNS, or (4) cardiovascular function. Additional data collected included information regarding severity and persistence of adverse events and the timing of appearance of the complication. Data regarding ASA class, a stratification of risk of general anesthesia, were also collected.

RESULTS

Data from a local medical center

We identified 41 patients with complications associated with ISB performed between January 1991 and February 2005. Specific data were not available on the training, experience, and complication rate of each of the different anesthesiologists responsible for these 41 patients. There were 27 peripheral neurologic, 3 CNS, 6 respiratory, and 5 cardiovascular complications (Table I). Anesthetic toxicity was the likely cause of all 5 cardiovascular events and 1 of the CNS events (case 29). Of these complications, 35 occurred from January 1994 to January 2005, during which time 3,172 interscalene blocks were performed, for an estimated complication rate of 1.1%.

Some complications were persistent, and many were serious and disabling (Table I). Of the 27 peripheral neurologic events, 11 (3 brachial plexopathies, 2 C6 nerve palsies, 2 radial nerve palsies, 1 lateral/posterior cord injury, 1 cervical plexopathy, 1 prolonged recurrent laryngeal nerve palsy occurring with prolonged Horner's syndrome, and 1 median neurapraxia) had recovery of normal function at a mean of 202 days (range, 10-760 days); 4 of these 11 neurologic deficits persisted for more than 6 months before recovery (cases 5, 6, 14, and 25). Persistent deficits were present in 14 patients (3 upper trunk injuries, 3 musculocutaneous nerve palsies, 3 C5/6 palsies, 2 brachial plexopathies, 1 posterior cord neurapraxia, 1 ulnar nerve palsy, and 1 radial nerve palsy) at a mean of 176 days (range, 17-416 days); only 5 of these 14 unresolved peripheral neurologic deficits (0.16% incidence) had more than 6 months of follow-up and were considered chronic (cases 1, 2, 7, 17, and 26). There were no data regarding recovery of peripheral neurologic function on 2 patients (1 upper trunk palsy and 1 C5/6 sensory loss). The 3 CNS complications (2 central blocks with paralysis and apnea requiring intubation and 1 tonic-clonic seizure) resolved by the following day with no long-term sequelae. The respiratory complications (3 pneumothoraces, 2 prolonged phrenic nerve palsies, and 1 pulmonary edema) resolved by a mean of 12 days (range, 2-37 days) with no long-term effects. Of the 5 cardiovascular complications, 3 (1 bundle branch block with tachycardia, 1 arrhythmia, and 1 premature ventricular contraction) resolved either the same day or the next day. The patient with a myocardial infarction had resolution of anteroinferior wall motion abnormality, ST-segment depression in leads V_3 and V_4, and T-wave inversion in leads V_3 through V_6 on the same day. A cardiac catheterization performed the next day demonstrated no coronary artery disease. There were no data regarding recovery for 1 of these cardiovascular events (arrhythmia).

We present 4 cases demonstrating the potential severity and permanence of complications of interscalene blocks in the local hospital series.

Case 1. A 45-year-old man elected to have an open cuff repair under an interscalene block, which was performed without the use of a nerve stimulator. Paresthesias were elicited during the block. After surgery, he had persistent atrophy and weakness of the anterior deltoid, as well as paresthesias radiating into the thumb and index finger after surgery. Electromyography (EMG) demonstrated neurologic injury in the fifth and sixth cervical nerve distributions. The patient's deficits had not resolved at his 1-year follow-up, when he relocated across the country.

Case 2. A 53-year-old man underwent a shoulder hemiarthroplasty for osteoarthritis. An ISB was administered with a 22-gauge simplex needle and a nerve stimulator after a triceps twitch was elicited at 0.3 mA. The patient was given 40 cm^3 of 0.375% bupivacaine with 1:200,000 epinephrine. He felt diaphoretic and warm and had nausea during placement of the block. Although no abnormalities were detected during his hospital stay, weakness of the deltoid, external rotators, and biceps brachii was

Table I Complications of ISB at a local medical center

Case No.	Complication	Surgery	Recovery (d)*	Last follow-up (d)†	No Follow-up data available
	Peripheral neurologic				
1	C5/6 palsy	Open RTC debridement, biceps tenodesis		360	
2	Upper trunk injury	TSA		405	
3	Brachial plexopathy	Open anterior and posterior Bankart repairs	27		
4	Posterior cord neurapraxia	Shoulder hemiarthroplasty and LOA		17	
5	Lateral/posterior cord injury	Open reduction for chronic dislocation, subscapularis repair	336		
6	Brachial plexopathy	Open RCR	409		
7	Brachial plexopathy	Open Bankart		398	
8	Cervical plexopathy	TSA	129		
9	C6 palsy	Revision open Bankart	83		
10	Persistent Horner's syndrome/hoarseness	Open Bankart	24		
11	C6 palsy	Anterior glenoid bone graft	10		
12	C5/6 sensory loss	Unknown			1
13	Upper trunk palsy	Hemiarthroplasty			1
14	Brachial plexopathy	Open Bankart	305		
15	C5/6 palsy	TSA		45	
16	C5/6 palsy	TSA		179	
17	Brachial plexopathy	Open RCR		266	
18	Upper trunk injury	Hemiarthroplasty, nonprosthetic glenoid arthroplasty		18	
19	Upper trunk injury	Revision hemiarthroplasty		39	
20‡	Radial nerve palsy	Revision TSA	24		
21‡	Ulnar nerve palsy	Open RCR		86	
22‡	Musculocutaneous nerve palsy	Open Bankart, interval closure		62	
23‡	Musculocutaneous nerve palsy	Open Bankart		62	
24‡	Radial nerve palsy	Revision hemiarthroplasty	115		
25‡	Median neurapraxia	Open Bankart	760		
26‡	Radial nerve palsy	Revision hemiarthroplasty, humeral cerclage		416	
27‡	Musculocutaneous nerve palsy	Hemiarthroplasty		112	
	CNS				
28	Central block	Revision TSA	1		
29	Tonic-clonic seizure	Revision hemiarthroplasty	0		
30	Central block	Shoulder arthroscopy	1		
	Respiratory				
31	Phrenic nerve palsy (persistent)/ intractable hiccups	Arthroscopic RCR, open ORIF for bony Bankart	37		
32	Pneumothorax	Coracoclavicular screw	5		
33	Pneumothorax	Percutaneous pin removal	3		
34	Pneumothorax	Revision hemiarthroplasty	2		
35	Phrenic nerve palsy (persistent)/ aspiration pneumonia	I&D for olecranon bursa	24		
36	Pulmonary edema	Shoulder MUA	2		
	Cardiovascular				
37	Myocardial infarction	Open biceps tenodesis, subscapularis repair	0		
38	Tachycardia, bundle branch block	Hemiarthroplasty	1		
39	Arrhythmias	Anterior glenoid bone graft and capsular reconstruction	1		
40	PVCs	Open RCR	0		
41	Arrhythmia, hypotension	Revision TSA			1

RCT, rotator cuff tear; *TSA,* total shoulder arthroplasty; *LOA,* lysis of adhesion; *RCR,* rotator cuff repair; *ORIF,* open reduction internal fixation; *I&D,* incision and drainage; *MUA,* manipulation under anesthesia.

*After administration of block.

†Since administration of block, if no recovery of function.

‡Possibly related to surgical procedure.

noted at his 2-week postoperative examination. EMG revealed an upper trunk injury. His weakness and severe pain persisted at his most recent follow-up, 13 months after surgery.

Case 7. A 44-year-old woman underwent an open anterior labral repair with use of ISB. Paresthesias were noted in the index and middle fingers at the time of the block, which was given with a nerve stimulator at a current on 0.4 mA. She was administered 30 cm^3 of 0.375% bupivacaine. Two weeks postoperatively, weakness in the index flexor digitorum profundus and flexor pollicis longus was noted on physical examination; denervation was documented on EMG. Weakness was persistent at a 1-year follow-up visit.

Case 36. A 46-year-old woman underwent open repair of a ruptured subscapularis and tenodesis of the biceps tendon. An ISB was administered with 20 cm^3 of 0.375% bupivacaine and 1:200,000 epinephrine introduced via a 22-gauge simplex needle after a twitch of the pectoralis major was elicited with a current of 0.6 mA applied by use of a nerve stimulator. The patient complained of shortness of breath and chest heaviness, and an electrocardiogram showed ST depression in the anterior leads along with bradycardia. The needle was withdrawn, and lidocaine and atropine were given; supraventricular tachycardia subsequently developed. The plan for surgery was abandoned. Laboratory studies showed elevation of the patient's cardiac enzyme levels, and a cardiac echocardiogram demonstrated transient small focal wall motion abnormality. She underwent cardiac catheterization that did not suggest any underlying coronary artery disease. It was thought that anesthetic toxicity from an intravascular bolus of bupivacaine was responsible for the event. She was discharged home and underwent successful surgery 1 week later under general anesthesia. No further cardiac events were noted.

A nerve stimulator technique[2,7] was used for 19 of the 27 cases associated with peripheral neurologic complications, all cases associated with CNS complications, 5 of the 6 cases associated with respiratory complications, and 4 of the 5 cases associated with cardiovascular complications. The original Winnie technique for eliciting paresthesias[46] was used for 1 case associated with a neurologic complication (C5/6 palsy) and 1 case associated with a respiratory complication (pneumothorax). No data regarding technique were available for the remaining cases (7 neurologic, 1 respiratory, and 1 cardiovascular complication). We were unable to recover data regarding the total number of blocks performed with each technique during the time period under study.

Of the 41 patients, 19 noted acute problems during administration of the block (Table II) whereas no problems were noted during administration in the remaining 22.

The rate of complications overall was 1.14%. There was a strong correlation between the complication rate and the number of blocks performed by each anesthesiologist (Figure 1 and Table III).

Table II Events noted either during administration of block or during surgical procedure

Case No.	Acute event
1	Paresthesias with block
2	Diaphoretic/warm during block, nausea
3	—
4	—
5	—
6	—
7	Paresthesia into index finger with block
8	—
9	Stimulator needle needed redirecting several times
10	Horner's/hoarseness upon induction
11	—
12	—
13	—
14	—
15	—
16	Ringing in ear with block
17	—
18	—
19	—
20	—
21	—
22	—
23	Third digit paresthesia
24	—
25	—
26	—
27	—
28	Became unresponsive and apneic, pupils dilated
29	Generalized seizure for 1 min, followed by 3 more after placement of block
30	Poor respirations, paralysis, hypotension after block; intubated, bagged
31	Seizure-like activity noted during placement of block, lightheaded, tachycardia
32	Chest pain and hoarseness after block
33	Air aspirated after block placement, chest pain followed
34	Mild discomfort during block
35	—
36	Acute SOB on transfer to operating room table, desaturated, bronchospasm
37	SOB, ST depression (anterior leads), bigeminy/bradycardia after block
38	Anxious after block, tachycardic, left bundle branch block after induction with general
39	Sinus bradycardia after block; SVT/junctional tachycardia postoperatively
40	PVCs during block; multiple PACs, PVCs, and hypotension intraoperatively
41	—

SOB, Shortness of breath; *SVT,* supraventricular tachycardia; *PAC,* premature atrial contractions; *PVC,* premature ventricular contractions.

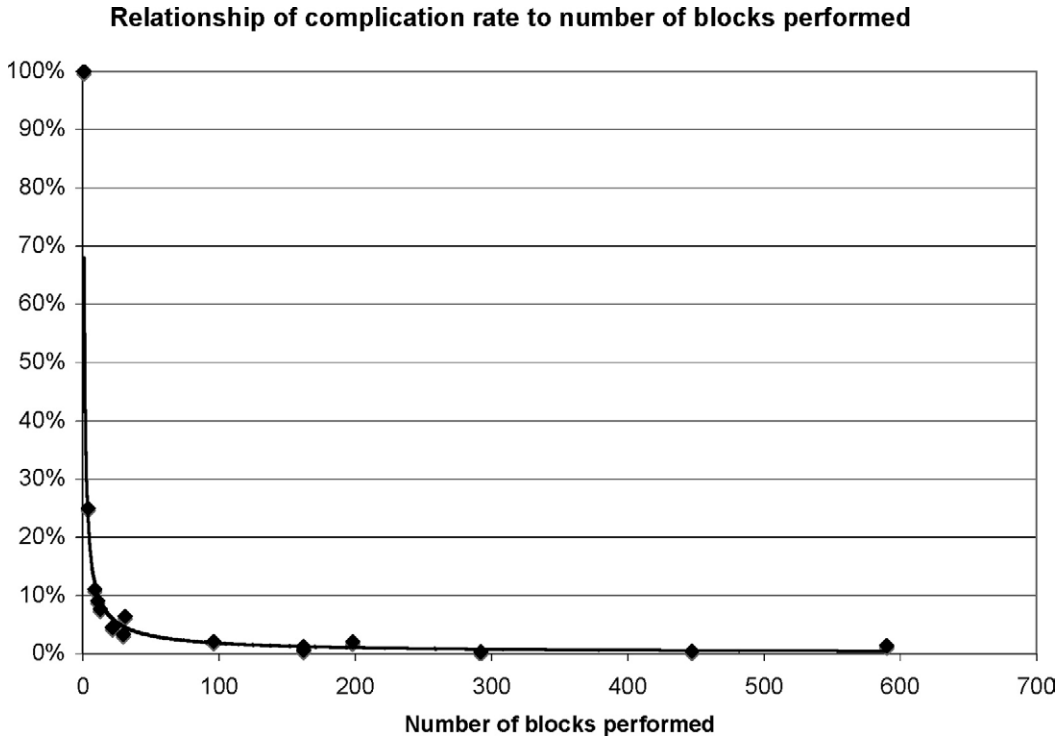

Figure 1 The complication rate is strongly correlated with the number of blocks performed. The relationship is well approximated by the following formula: Complication rate = 0.68 × (No. of blocks performed)$^{-0.7878}$. This formula correlated with the data at $R^2 = 0.8994$.

Table III Correlation between complication rate and number of blocks performed by each anesthesiologist

	ISBs performed	Complications	Complication rate
Anesthesiologist			
A	1	1	100.00%
B	4	1	25.00%
C	9	1	11.11%
D	11	1	9.09%
E	13	1	7.69%
F	31	2	6.45%
G	22	1	4.55%
H	30	1	3.33%
I	96	2	2.08%
J	198	4	2.02%
K	590	8	1.36%
L	162	2	1.23%
M	162	1	0.62%
N	447	2	0.45%
O	292	1	0.34%
Total	2068	29	1.40%

ISB, interscalene block.

The mean complication rate for anesthesiologists performing less than 100 blocks was 5%, whereas the mean rate of complications for anesthesiologists performing more than 100 blocks was 1% ($P = .0015$ by Mann-Whitney *U* test).

Table IV Complications of ISB in a national database*

Adverse Event	N†	% of block complications
Peripheral neurologic injury (brachial plexus)	12	43%
CNS injury	4	14%
Spinal cord injury	1	4%
Brain damage	3	11%
Respiratory injury	10	36%
Pneumothorax	7	25%
Phrenic nerve palsy	2	7%
Respiratory distress	1	4%
Death	3	11%

CNS, central nervous system.
*ASA Closed Claims Database. Some claims had multiple complications.
†Number of complications due to ISB.

Complications from a national database

A total of 6,446 claims, with 1,671 resulting from regional anesthesia, had been closed at the time of this report. Twenty-eight claims (2% of regional anesthesia claims) were alleged to be associated with

Table V ASA Closed Claims data regarding severity of event

Injury severity	N*	% of block complications
Emotional only	1	4%
Temporary	15	54%
Insignificant	1	4%
Minor	7	25%
Major	7	25%
Permanent	12	43%
Minor	2	7%
Significant	4	14%
Major	2	7%
Grave	1	4%
Death	3	11%

*Number of adverse outcomes related to ISB.

Table VI ASA Closed Claims data regarding timing of event appearance

Time when injury became apparent	N*	% of block complications
Intra-anesthesia	5	18%
PACU	5	18%
Ward/floor	1	4%
After discharge	8	29%
Unknown	9	32%

*Number of adverse outcomes related to ISB.

Table VII ASA Closed Claims data regarding ASA class of patients with adverse events*

ASA group	N†	% of block complications
Unknown	6	21%
1-2	18	64%
3-5	4	14%

*ASA stratification of patient risk for complications from anesthesia.
†Number of patients with adverse outcomes from ISB.

complications from ISB (Table IV). Of these 1 was reported in the 1970s, 13 in the 1980s, and 14 in the 1990s. There were 12 peripheral neurologic complications (all brachial plexus), 4 CNS injuries (3 cases of brain damage and 1 spinal cord injury), 2 phrenic nerve injuries (1 temporary, 1 permanent), 7 pneumothoraces, and 3 deaths.

Similar to the data from the local medical center, many of the complications were enduring and disabling. Of the 28 injuries, 12 were considered permanent (Table V). Many of the complications were not recognized during hospitalization (Table VI). At least 18 of the events occurred in otherwise healthy patients, who might have been at low risk from general anesthesia (Table VII).

DISCUSSION

The data presented here indicate that ISB can be associated with substantial and persistent complications. Neurologic complications were often chronic—that is, they lasted 6 months or longer. Significant respiratory, CNS, and cardiovascular events occurred but did not lead to permanent sequelae (with the possible exception of 1 patient with an arrhythmia for whom no follow-up data were available).

The ASA Closed Claims data corroborate the risks of ISB shown with the medical center data and again demonstrate that complications associated with ISB can be chronic. Of the 28 events, 18 occurred in patients in ASA class 1 or 2—that is, patients who may have been at low risk for complications from a general anesthetic. Of the 28 adverse events, 8 were not recognized until after discharge.

Previous reports have described complications from ISB, including neurologic events such as brachial plexus neuritis,[37] complete and partial brachial plexus palsy or nerve injury,[4,5,8,41,44,45] prolonged Horner's syndrome,[1,35,36] prolonged recurrent laryngeal nerve palsy,[35] complex regional pain syndrome,[20] and auditory disturbances.[34] Respiratory events including pneumothorax,[8] phrenic nerve palsy,[43] bronchospasm,[27,39] and reduction of pulmonary function tests[42] have also been reported, as have CNS complications such as central blocks,[14,17,32,38] permanent spinal cord injury,[6,32] and seizures.[15,23,24] Cardiovascular complications, such as myocardial infarction,[18] have been reported, as well as profound hypotension and bradycardia, which have been attributed to the Bezold-Jarisch reflex.[16] Local anesthetic toxicity can cause complications of CNS and cardiovascular function, including seizures, myocardial infarction, and arrhythmias. The range and severity of these complications have not been previously presented in the orthopaedic literature.

Our data can be compared with those from several published reports of ISB (Table VIII). A recent study by Weber and Jain[45] described the experience with ISB via a nerve stimulator in the community setting. There were 8 complications reported in 218 patients (3.67% incidence): 1 seizure (0.46% incidence), 1 episode of cardiovascular collapse (0.46% incidence), 4 episodes of severe respiratory distress (1.83% incidence), and 2 peripheral neurologic injuries (0.92% incidence). One of the peripheral neurologic injuries, resulting in weakness and atrophy of the volar forearm and numbness in the lateral antebrachial cutaneous nerve, became chronic (0.45% incidence). The local hospital series in our study includes almost 6 times the number of patients in the study of Weber and Jain, with a broader range of complications.

Table VIII Comparison of our data with recent literature*

	Medical center		ASA database		Weber and Jain[45]		Bishop et al[7]		Borgeat et al[8]	
	Total (%)	Chronic (%)	Total	Chronic	Total (%)	Chronic (%)	Total (%)	Chronic (%)	Total (%)	Chronic (%)
Total	41 (1.13)	5 (0.16)	28	12	8 (3.67)	1 (0.49)	12 (2.34)	1 (0.20)	76 (14.6)	5 (0.96)
Peripheral neurologic	27 (0.73)	5 (0.16)	20		2 (0.92)	1 (0.49)	12 (2.34)	1 (0.20)	74 (14.2)	5 (0.96)
CNS	3 (0.09)	0 (0)	5		1 (0.46)	0 (0)			1 (0.19)	0 (0)
Central blocks	2 (0.06)		1							
Spinal cord injury			1							
Brain damage			3							
Seizure	1 (0.03)		4		1 (0.46)					
Incoherent speech									1 (0.19)	
Respiratory	6 (0.19)	0 (0)	10		4 (1.83)	0 (0)			1 (0.19)	0 (0)
Pneumothorax	3 (0.09)		7						1 (0.19)	
Prolonged phrenic palsy	2 (0.06)		2							
Pulmonary edema	1 (0.02)									
Airway injury			0							
Respiratory distress			1		4 (1.83)	0 (0)				
Cardiovascular	5 (0.18)	0 (0)	3		1 (0.46)					
Myocardial infarction	1 (0.02)									
Arrhythmia	4 (0.17)		1							
Cardiovascular collapse			2		1 (0.46)	0 (0)				
Deaths			3							
Emotional disturbances			0							
Miscellaneous			0							

*Some claims had multiple complications.

Another recent publication describes the experience of interscalene regional anesthesia in a university hospital, where a specialized team of anesthesiologists performs the procedure using a nerve stimulator.[7] Of the blocks, 97% were considered successful, with 12 peripheral neurologic complications in 512 patients (2.34% incidence). Only 1 was persistent (0.20% incidence), resulting in paresthesias in the ring and little fingers. No respiratory complications, CNS complications, or cardiovascular complications were encountered. The authors attributed the safety and efficacy in their series to the performance of the blocks "by a group of anesthesiologists who were dedicated to the concept of regional anesthesia in their practice," and they concluded that "the experience of our anesthesia team may have contributed to our lower complication rate as they are dedicated to the concept of regional anesthesia and practice it on a daily basis."[7] Their data indicate that 568 ISBs were administered over a period of 2.5 years, for a mean of 4.4 ISBs per week by a small group of anesthesiologists.

A recent prospective report of ISBs administered with a nerve stimulator suggests that only a small percentage of patients manifested chronic peripheral neurologic injuries.[8] At 10 days after surgery, 14% of patients with peripheral neurologic complications were symptomatic. However, by 6 months, only 0.96% remained symptomatic.

Although controversy exists regarding the value of a nerve stimulator compared with the paresthesia technique,[21,31] the local medical center data in our report suggest that use of a stimulator does not guarantee a safe block. Whereas the presence of paresthesias during administration of the block may be associated with adverse neurologic events,[4] only 3 of the 27 neurologic events in the medical center series were associated with this occurrence. It has been suggested that ultrasound guidance for administration of the block can diminish the risk of complications and may become the gold standard technique.[29]

This study must be viewed in light of certain limitations. First, the retrospective nature of the data collection in both the local medical center and the national

experiences prevented our determining the precise incidence of these complications. Second, it is recognized that nerve injuries can result from shoulder surgery; thus, it cannot be stated with certainty that the complications reported here were the result of the interscalene block. Third, follow-up beyond 6 months was not available for 9 of the neurologic complications showing no recovery. It is not known which of these became chronic or permanent. Finally, although more experienced anesthesiologists tended to have lower complication rates, we were unable to determine the relationship between anesthesiologist experience and risk of complication.

Despite these limitations, the data presented here demonstrate that substantial complications can follow the use of ISB for shoulder surgery and that chronic peripheral neurologic complications can occur. These chronic neurologic problems can substantially compromise what might be an otherwise successful shoulder operation. The burden of treatment of these adverse outcomes often falls on the orthopaedic surgeon rather than the anesthesiologist. The data from the ASA Closed Claims database emphasizes that these complications can lead to litigation; the potential liability of the orthopaedic surgeon in the choice of anesthetic in these cases is not known. Patients, surgeons, and anesthesiologists must all be aware of these possible complications, understanding that the factors determining the magnitude of the risk for these complications may vary widely among institutions, among anesthesiologists, and among groups of patients.

REFERENCES

1. Al-Khafaji JM, Ellias MA. Incidence of Horner syndrome with interscalene brachial plexus block and its importance in the management of head injury. Anesthesiology 1986;64:127.
2. Amundson L, Davies J. Anesthesia for shoulder procedures. In: Rockwood CA, Matsen FA III, Wirth MA, Lippitt SB, editors. The shoulder. 3rd ed. Philadelphia: Saunders; 2004. p. 269-81.
3. Arciero RA, Taylor DC, Harrison SA, Snyder RJ, Leahy KE, Uhorchak JM. Interscalene anesthesia for shoulder arthroscopy in a community-sized military hospital. Arthroscopy 1996;12: 715-9.
4. Auroy Y, Narchi P, Messiah A, Litt L, Rouvier B, Samii K. Serious complications related to regional anesthesia: results of a prospective survey in France. Anesthesiology 1997;87:479-86.
5. Barutell C, Vidal F, Raich M, Montero A. A neurological complication following interscalene brachial plexus block. Anaesthesia 1980;35:365-7.
6. Benumof JL. Permanent loss of cervical spinal cord function associated with interscalene block performed under general anesthesia. Anesthesiology 2000;93:1541-4.
7. Bishop JY, Sprague M, Gelber J, Krol M, Rosenblatt MA, Gladstone J, et al. Interscalene regional anesthesia for shoulder surgery. J Bone Joint Surg Am 2005;87:974-9.
8. Borgeat A, Ekatodramis G, Kalberer F, Benz C. Acute and nonacute complications associated with interscalene block and shoulder surgery: a prospective study. Anesthesiology 2001;95: 875-80.
9. Brand F, Taeger K. The combination of general anesthesia and interscalene block in shoulder surgery. Anaesthesist 1991;40: 537-42.
10. Brown AR, Levine WN. Complication rates of scalene regional anesthesia. J Bone Joint Surg Am 2002;84:1891-2, author reply 1892-3.
11. Brown AR, Parker GC. The use of a "reverse" axis (axillary-interscalene) block in a patient presenting with fractures of the left shoulder and elbow. Anesth Analg 2001;93:1618-20.
12. Brown AR, Weiss R, Greenberg C, Flatow EL, Bigliani LU. Interscalene block for shoulder arthroscopy: comparison with general anesthesia. Arthroscopy 1993;9:295-300.
13. Cheney FW, Domino KB, Caplan RA, Posney KL. Nerve injury associated with anesthesia: a closed claims analysis. Anesthesiology 1999;90:1062-9.
14. Cook LB. Unsuspected extradural catheterization in an interscalene block. Br J Anaesth 1991;67:473-5.
15. Crews JC, Rothman TE. Seizure after levobupivacaine for interscalene brachial plexus block. Anesth Analg 2003;96:1188-90.
16. D'Alessio JG, Weller RS, Rosenblum M. Activation of the Bezold-Jarisch reflex in the sitting position for shoulder arthroscopy using interscalene block. Anesth Analg 1995;80:1158-62.
17. Dutton RP, Eckhardt WF III, Sunder N. Total spinal anesthesia after interscalene blockade of the brachial plexus. Anesthesiology 1994;80:939-41.
18. Edde RR, Deutsch S. Cardiac arrest after interscalene brachial-plexus block. Anesth Analg 1977;56:446-7.
19. Fanelli G, Casati A, Garancini P, Torri G. Nerve stimulator and multiple injection technique for upper and lower limb blockade: failure rate, patient acceptance, and neurologic complications. Study Group on Regional Anesthesia. Anesth Analg 1999;88:847-52.
20. Gillespie JH, Menk EJ, Middaugh RE. Reflex sympathetic dystrophy: a complication of interscalene block. Anesth Analg 1987; 66:1316-7.
21. Gologorsky E, Tenicella RA. Does the interscalene block require paresthesia? Reg Anesth 1997;22:387-8.
22. Greek R, Maurer P, Torjman M, Schieren H, Finke J, Lessin J, Marr A, Fenlin J, Seltzer J. Effect of general anesthesia vs interscalene block for shoulder surgery: postoperative pain and neuroendocrine responses. Reg Anesth 1993;18:68.
23. Korman B, Riley RH. Convulsions induced by ropivacaine during interscalene brachial plexus block. Anesth Analg 1997;85: 1128-9.
24. Kozody R, Ready LB, Barsa JE, Murphy TM. Dose requirement of local anaesthetic to produce grand mal seizure during stellate ganglion block. Can Anaesth Soc J 1982;29:489-91.
25. Kuflik P, Ankolekar A, Stuchin SA, Steinbach S, Bernstein R. Interscalene brachial plexus block anesthesia for upper extremity surgery. J Hand Surg [Am] 1986;11:246-8.
26. Lee LA, Posner KL, Domino KB, Caplan RA, Cheney FW. Injuries associated with regional anesthesia in the 1980s and 1990s: a closed claims analysis. Anesthesiology 2004;101:143-52.
27. Lim EK. Inter-scalene brachial plexus block in the asthmatic patient. Anaesthesia 1979;34:370.
28. Lombard TP. The interscalene approach to block of the brachial plexus. S Afr Med J 1982;62:871-3.
29. Marhofer P, Greher M, Kapral S. Ultrasound guidance in regional anaesthesia. Br J Anaesth 2005;94:7-17.
30. Maurer P, Greek R, Torjman M, Lessin J, Marr A, Fenlin J, Seltzer J. Is regional anesthesia more efficient than general anesthesia for shoulder surgery? Anesthesiology 1993;79:A897.
31. Moore D. "No paresthesias-no anesthesia," the nerve stimulator or neither? Reg Anesth 1997;22:388-90.
32. Passannante AN. Spinal anesthesia and permanent neurologic deficit after interscalene block. Anesth Analg 1996;82:873-4.
33. Pollock RG, Brown AR, Flatow EL, Bigliani LU. Regional anesthe-

sia for shoulder arthroscopy: the interscalene block. Contemp Orthop 1993;26:452-7.
34. Rosenberg PH, Lamberg TS, Tarkkila P, Marttila T, Bjorkenheim JM, Tuominen M. Auditory disturbance associated with interscalene brachial plexus block. Br J Anaesth 1995;74:89-91.
35. Seltzer JL. Hoarseness and Horner's syndrome after interscalene brachial plexus block. Anesth Analg 1977;56:585-6.
36. Sukhani R, Barclay J, Aasen M. Prolonged Horner's syndrome after interscalene block: a management dilemma. Anesth Analg 1994;79:601-3.
37. Tetzlaff JE, Dilger J, Yap E, Brems J. Idiopathic brachial plexitis after total shoulder replacement with interscalene brachial plexus block. Anesth Analg 1997;85:644-6.
38. Tetzlaff JE, Yoon HJ, Brems J. Interscalene brachial plexus block for shoulder surgery. Reg Anesth 1994;19:339-43.
39. Thiagarajah S, Lear E, Azar I, Salzer J, Zeiligsohn E. Bronchospasm following interscalene brachial plexus block. Anesthesiology 1984;61:759-61.
40. Urban MK. The interscalene block for shoulder surgery. Tech Shoulder Elbow Surg 2004;5:61-5.
41. Urban MK, Urquhart B. Evaluation of brachial plexus anesthesia for upper extremity surgery. Reg Anesth 1994;19:175-82.
42. Urmey WF, McDonald M. Hemidiaphragmatic paresis during interscalene brachial plexus block: effects on pulmonary function and chest wall mechanics. Anesth Analg 1992;74:352-7.
43. Urmey WF, Talts KH, Sharrock NE. One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography. Anesth Analg 1991;72:498-503.
44. Walton JS, Folk JW, Friedman RJ, Dorman BH. Complete brachial plexus palsy after total shoulder arthroplasty done with interscalene block anesthesia. Reg Anesth Pain Med 2000; 25:318-21.
45. Weber SC, Jain R. Scalene regional anesthesia for shoulder surgery in a community setting: an assessment of risk. J Bone Joint Surg Am 2002;84:775-9.
46. Winnie AP. Interscalene brachial plexus block. Anesth Analg 1970;49:455-66.
47. Wu CL, Rouse LM, Chen JM, Miller RJ. Comparison of postoperative pain in patients receiving interscalene block or general anesthesia for shoulder surgery. Orthopedics 2002;25:45-8.